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Recommendations for Portable Supplemental Meteorological Instrumentation for Incident Response

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ABSTRACT

The Nuclear Regulatory Commission (NRC) staff requested technical assistance in recommending portable supplementary meteorological instrumentation which can be deployed to nuclear power plant sites in response to incidents. A supplementary meteorological system (SMS), whose primary function is to collect, analyze and disseminate supplemental meteorological information, is recommended. Instrument specifications are discussed along with maintenance and staffing requirements. A cost evaluation of the components is made.

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A. Introduction

The U. S. Nuclear Regulatory Commission (NRC) requested the Atmospheric Sciences Division at Brookhaven National Laboratory to provide technical assistance in evaluating types of supplementary meteorological instrumentation needed for incident response at nuclear power plant sites. The scope and objective of the request is given in FIN No. A 3317, titled, "Supplemental Meteorological Instrumentation for Incident Response." As defined in that document, the NRC request is to "survey and perform an evaluation of off-the-shelf meteorological instrumentation (including both direct and remote sensors) and data acquisition systems (including the capabilities of other Federal agencies) to supplement the on-site meteorological program and other locally available systems. Instrumentation should be portable, capable of being deployed in minimal time frame, and provide useful information for emergency planning and evaluation."

The supplemental instrumentation will be specified to meet needs that may arise in the event of an incident; it is be assumed that some information is available, either at the site or from a "viable backup meteorology measurements system" as specified in NUREG-0654/FEMA-REP-1 (NRC, 1980).

At the time of an incident there is an immediate operational need to define evacuation areas and to evaluate the consequences of radioactive releases to the atmosphere. Releases can be at any elevation, and knowledge of the upper level winds must be obtained to determine correct trajectory patterns. Sites are situated in nonuniform terrain; therefore, trajectory determination requires knowledge of winds at several points. A measure of stability is required to forecast the degree of horizontal and vertical spreading of effluents.

At the time of an incident the meteorological data will be required by various users: the meteorologist advising the Incident Response Team; personnel operating predictive models, either at the site or remotely; personnel representing the state (and/or local) authorities; NRC personnel at a headquarters incident response location. In addition, the public information media should have access to the data if they can be made available without interfering with essential operations.

Analyses after the incident include calculations of population exposure and/or interpretation of monitoring results to calculate (or confirm) magnitude cf releases to the atmosphere. Essentially, the same data needed for emergency operations are needed, in perhaps more detail, to calculate effluent transport and dilution with more sophisticated models.

B. Background

It is imperative that pertinent meteorological information be readily available when incidents occur at nuclear power plants. During such circumstances, it is essential that an information center be established as a focal point for collecting and disseminating meteorological data relative to the situation.

According to the proposed revision 1 to USNRC Regulatory Guide 1.23 (NRC, 1980), "all nuclear power plant facilities are required to maintain primary meteorological instrumentation capable of measuring wind direction, wind speed, and ambient air temperatures at a minimum of two levels on at least one tower or mast in order to obtain information required for a valid estimate of atmospheric diffusion at a particular site. Furthermore, at least one set of meteorological measurements is to be made at the height of release of possible radioactive material to the atmosphere. Analog or digital recording of the data must be available in the reactor control room for use during plant operation."

It has been recommended in NUREG-0654 that there be a backup meteorological measurements system to provide information when the primary system is not in service, thereby assuring the availability of basic meteorological information at all times. It would be useful and perhaps mandatory, that when incidents occur, portable supplementary instrumentation be readily available to provide meteorological information at preselected locations and heights not necessarily under observation by the primary or backup systems. It is therefore recommended that a Supplementary Meteorological System (SMS) be designed and implemented with equipment for use in incident response. It should be capable of providing basic measurements where needed to better define plume trajectories and plume concentrations in fast turnaround times. The output from the SMS will further assure that meteorological data are available if and when a state of emergency exists at any nuclear power plant.

C. General SMS Description

1. Characteristics of a SMS

A SMS whose primary function is to collect, analyze, and disseminate supplemental meteorological information at nuclear power plant sites during incidents is recommended. It should consist of compatible modular elements, be completely portable, have the capability of reaching operational status in a reasonable time period, and be able to establish rapid data links. The SMS will be composed of off-the-shelf equipment, eliminating the need for instrument development. It should accept real-time information collected from an upper-wind- and -temperature-sensing system and from nearby off-site remote stations. The SMS should have additional communication links for transmitting data to other sites. A microcomputer could be used for data collection, processing, and dissemination.

The components making up the SMS could include a number of meteorological instruments and/or systems for determining the wind direction, wind speed, and a means of measuring the diffusive turbulent nature of the wind. Remote stations used for near-ground level heights (i.e., 10 meters) could be made up of simple devices, such as wind vanes and cup anemometers, while others could be more complicated and include bidirectional-vane sensors, hot wire anemometry, acoustic arrays, etc. In the past several years, systems utilizing remote sensing have been developed to measure the upper-wind flow, temperature, and turbulence. They include Doppler radar, lidar, and Doppler acoustic sounders. Another recently developed system for determining vertical profiles uses simple instruments and a tethered kite or balloon. Each of the above could be used as supplemental instrumentation, and an evaluation of each is made in this document.

2. Deployment

A SMS, put together from modular elements to form a unit housed in a portable vehicle, could be located at some convenient center and deployed to wherever it was needed. Another option is to provide each nuclear power plant with supplemental equipment for use when required. If the first option is selected, arrangements must be made for deployment.

The time required to deploy a SMS to a site will be minimal if it is standing by in "ready condition" at a strategically located regional center. If details for deployment have been prearranged, it is estimated that a SMS could be on location anywhere in the country within the first twelve hours after a declared incident, even at the most distant power plant location. It should be possible to establish the first data links to on-site meteorological information and reach initial operational status within a few hours after arrival. Information from the remote stations and other meteorological data can be added to amplify the SMS output as time allows.

The time required to deploy a SMS and reach operational status should be determined by prior arrangements to transport the system, availability of necessary data links at a particular site, and availability of qualified personnel ready to operate the system.

3. Spatial Distribution of Remote Stations

Many nuclear power plants are located along coastal zones, in river valleys, or in rough terrain where downwind diffusion patterns tend to be distorted. To determine the effect of these irregularities on transport and diffusion, meteorological measurements must be made at selected locations. Automatic weather stations have been developed for determining the wind direction, wind speed, and turbulence of nearby off-site locations to aid in assessing particular diffusion problems. Self-contained portable battery-operated units which can telemeter information over line-of-sight distances sometimes using relay stations are now considered reliable for unattended use in various field programs. The number and spatial distribution of such subsystems depend entirely on the configuration of the terrain at a particular location. It is estimated that no more than <u>four</u> such remote stations, located within ten miles, would be required to fulfill this requirement even at the plant located on the most irregular terrain.

In addition to remote station locations where rough terrain measurements are needed, a portable vertical sounding system could be utilized at any near-site position where vital upper-level information is required. The ability to provide portable supplemental instrumentation will improve the spatial resolution of measur ...s normally obtained from the primary or backup programs.

The output from the remote stations and vertical sounding system will be received by the SMS to provide additional information to determine the extent of their influence on diffusion patterns.

4. Time Resolution of Measurements

The Americal National Standard for Obtaining Meteorological Information at Nuclear Power Sites (ANS-2.5) gives the time resolution to obtain the standard deviation of the horizontal wind direction fluctuations (σ_θ). It requires "no less than 180 instantaneous values of lateral wind direction during sampling period (i.e., if the sampling period is 15 minutes, values sampled at every 5-second interval or less are acceptable)." Time resolutions on this time scale are routinely obtained with the most modern meteorological instrumentation. It is common practice to use 15-minute averages of meteorological information to determine the parameters used in diffusion calculations at nuclear power plants. The averaged data or functions of the data will provide parameters needed for diffusion calculations.

5. Data Acquisition

The data acquisition system must be capable of sampling data from a variety of input channels at rates fast enough to satisfy the resolution requirements discussed in (4) above. It must be capable of transforming the data into usable information, i.e., do conversions to engineering units, produce averages and variances, etc., in real time. Therefore, the system should be programmable. Specifications on input devices will determine what input interfaces will be required, e.g., analog-to-digital converters, preamplifiers, multiplexers, etc. Input channels may be of different types. A microcomputer with a line printer, graphics terminal, and either disk drives or some type of tape drive will satisfy the above requirements. The graphics terminal can provide graphical displays of selected instrument outputs to display that the equipment is operating properly. The line printer will serve to give permanent hard copy of all alphanumeric transactions. Alternatively, or in addition, a graphics hard copy unit can provide hard copy of plots as well as copy of all alphanumeric transactions from the graphics terminal screen.

Since routines for data acquisition, computation, graphical display, and data access must be written, the microcomputer should have a programming language such as FORTRAN or BASIC.

6. Data Dissemination

ANS 2.5 states that data systems must be capable of being interrogated remotely by means of the ... interface with a minimum 24-hour recall of collected data. The data format should be fixed and include site identification, Julian day, time (LST-24 hours), and meteorological parameters in engineering (metric) units including height of measurement. A site descriptor and the meteorological data formats as given in the proposed revision 1 to USNRC Regulatory Guide 1.23 (NRC, 1980) could be used. In addition, it is suggested that data be transferred via an RS232C interface to a computer link in an existing computer network such as ARPANET. (ARPANET is an operational, resource-sharing, host-to-host network linking a wide variety of computers at research centers sponsored by Defense Advanced Research Projects Agency (DARPA) and other DOD and non-DOD activities in continental

United States, Hawaii, Norway, and England.) This data transfer could be initiated from the SMS at regular intervals. Data would then be available by dialing the SMS or by dialing a computer on the network. In this way, NRC personnel could access data directly from the SMS without conflict for telephone lines from other users who would access data from the network. To satisfy these needs, the microcomputer must have an RS232C interface with at least two serial line inputs to connect to communications. Two modems will be required; the one used for remote interrogation purposes should be of the "automatic-answer" type. Transfer rates of 300 baud asynchronous should be adequate for remote interrogation; 1200 baud with a protocol to be decided might be useful for transferring data from SMS to a computer network.

7. Archiving

Data collected and disseminated during an incident must be archived to be available for later calculations. Records must be kept in both analog and digital form. While disk storage provides rapid access during an incident, permanent digital archiving should be made by means of 9-track magnetic tape to be accessible by most large computer systems. An archival format should consist of fixed-length records and include site identification, date, time, meteorological parameters in engineering units, height of measurements, and, possibly, other calculated parameters.

D. System Component Evaluation

1. Specifications for Individual Components

A wide variety of system components is available for use in a SMS. It is recommended that they be required to meet the specifications as given in the ANS-2.5 Guide and listed in Table I.

Table I	Wind Direction	Wind Speed	Temperature
Accuracy	±5°	±0.22 mps	±0.5°C
Starting threshold	<0.45 mps	<0.45 mps	
Range	0-360°, 0-540°		
Temperature difference	±0.15°C per 50-meter height interval		
Time	±5 minutes of actual time for all recording systems		
σ_θ	If the wind direction sensor is to be used to determine σ_θ, the damping ratio must be between 0.4 and 0.6 inclusive, with a deflection of 15 degrees and the delay distance not to exceed 2 meters.		

2. Evaluation of Systems

Material released to the atmosphere in effluent plumes is subjected to a complicated process, varying with the conditions of release, wind, turbulence, and other factors associated with local terrain or buildings. Attempts to determine the downwind track and concentration of the material are usually made by measuring various conditions of the atmosphere that are pertinent to the direction that the effluent takes and the diffusion it undergoes. If the measuring system is complex and sophisticated, then the investigation itself adds complication to complication. No simple measuring system exists to solve these problems, but some systems are relatively more simple than others and have proven reliabilities and performance.

The response of the sensors and recording mechanism must be compatible with the scale of the diffusion problem to be solved. For a dispersing plume in the atmosphere, sensor response of no more than a cycle per second is sufficient to produce necessary fluctuation information. Ultra-fast response equipment, such as sonic and hot-wire anemometry, is therefore not required for this purpose.

Remote sensing systems including Doppler radar, lidar, and Doppler acoustic sounders are still being developed and show promise as potential tools for monitoring the wind, temperature, and turbulence parameters of the upper atmosphere. Doppler acoustic sounders have reached field operational status for determining upper wind and boundary layer conditions. Degree of performance and reliability of wind measurements from acoustic sounding systems are presently being investigated in intercomparison experiments and by several field operational users. Absolute temperature measurements from these systems have not been developed to date. Although these systems are becoming less complicated to operate and more operational, a degree of skepticism remains concerning their overall performance in atmospheric diffusion determinations. They are not recommended as supplemental equipment at this time.

Conventional wind equipment (wind vanes, propellers, cup anemometers, etc.) is still used in various systems where portable supplemental instruments are needed. Remote stations, using conventional equipment, are available and designed to provide wind measurements which might be required at near off-site locations during incidents at nuclear power plants. They are portable, can be set up and made operational in reasonable time periods, and meet all the specifications required in Table I. It is recommended that this type of component be considered for inclusion in a SMS.

Vertical profiles of wind and temperature can be obtained from tethered balloon sounding systems, which can be set up and made operational in minimal time to provide information needed to supplement the data available from the primary equipment in operation at each site. Such equipment has the advantage of providing upper wind and temperature data to heights of 800 meters which eliminates the expense of erecting a portable tower that would otherwise be required. It is recommended that a vertical profiling system of this type be included as part of a SMS.

A useful and practical SMS should be composed of two basic atmospheric measuring components, i.e., remote stations and a vertical profiling system whose central recording system is housed in a portable, self-powered van from which communication links could be made. Such a SMS could be developed, maintained, calibrated, and stationed as a unit in some convenient location for rapid deployment to a particular site when needed. Another option to consider is that of requiring each operating nuclear power plant to have supplementary equipment (as described in this document) available for use when requested by the NRC. The output from the system components could be routed into existing on-site recording, formating, and transmission schemes as recommended in NUREG-0654.

3. Communication Elements and Links

A communication link is required to monitor remote station measurements. It is usually accomplished by conditioning the sensor outputs, modulating them, and transmitting those data by means of radiotelemetry. The data can be transmitted continuously or formatted to time average at the remote station before transmission. The resulting information is then transmitted on standard frequency range and received by an FM receiver. If more than one remote station is to be monitored, a multiplexer is required to separate the signals. The data are demodulated and become input data to a microcomputer. Systems using communication links such as those described above are readily available from a variety of manufacturers as off-the-shelf items.

Vertical sounding systems, positioned some distance away from the central collecting center, must also have a communication link. Such systems, using the same radiotelemetry link as described above, are available as off-the-shelf items, although the number of manufacturers making them is limited.

Communication links within the central collection site include input and output modems to a microcomputer. A wide variety of microcomputers are available which are capable of accepting many types of input data.

Output information for standard interfacing to peripheral equipment and RS232C interrogation is common to most microcomputers. It is recommended that data from the microcomputer be transferable via two modems. One would interface directly to an existing computer network for external use, while the other would be available to the NRC for direct access to processed data from the SMS. This was described in more detail in the section on data dissemination.

4. Power and Lightning Protection

The electrical power required to operate the internal equipment in the portable van should be available from two sources: an auxiliary outlet incorporated into the van system for connection to an external source of electrical power, when available; a gasoline-powered electrical generator, housed in a rear compartment to supply internal power. The external components, i.e., the upper-wind-sensing and transmitting system and the remote stations should operate from the normal battery configuration provided by the manufacturer.

The van should be provided with the best form of lightning protection. The remote stations should have grounding rods to assist in diverting large atmospheric electrical static discharges.

5. Cost Evaluation of Components (January 1980)

The following cost evaluations made in early 1980 gives the price range of component systems suggested in this document.

a. Remote Stations

Composed of sensors for measuring the wind direction, wind speed, stability, data conditioning, 10-meter tower, and transmission radiotelemetry equipment. $6000 to $7000/station.

Radiotelemetry and processor $6000 to $7000/one required.

b. Vertical Sounding System

Composed of airborne sensor for measuring the wind direction, wind speed, temperature, radiotelemetry transmitter, telemetry receiver and processor, output displays, and recorders. $12,000 to $14,000

c. Microcomputer

Programmable in BASIC or FORTRAN. Consists of microprocessor, memory, disk drives, line printer, magnetic tape drive, possibly graphics terminal, two serial RS232 compatible lines for communication links plus modems and necessary interfaces to input data from meteorological instruments.

$15,000 to $20,000

d. Programming and System Formating

Develop software to display and archive collected data at the SMS. Develop software to allow user to dial from remote sites. Program diffusion calculations. Document software and programs.

$10,000 to $20,000

e. Mobile Instrument Step Van

A self-propelled and -powered unit to act as a center for the collection and transmission of data.

Composed of laboratory space, storage compartments, air conditioner, and heaters.

$18,000 to $23,000

Generator for power $2,550

f. Calibration

Equipment is required to satisfy individual component and system calibrations.

$5,000

It is recommended that complete systems, i.e., sensors, communication links, etc. be obtained and guaranteed by one manufacturer. It is more practical and economical over a period of time to rely on one source for operational and repair assistance than on many.

E. System Design and Operation

1. System Components

The consensus of those individuals involved in meteorologica functions at Three Mile Island (TMI) was that portable supplemental meteorological equipment should be available to supply additional measurements where needed at the site of an incident and at selected near off-site locations. There is overall agreement that it would be valuable to have a portable vertical sounding system to determine the wind and temperature structure at specific times and heights with altitude resolution of 50 to 100 meters.

The basic configuration of a SMS, depicted in the block diagram of Figure 1, consists of from one to four remote station components, a vertical profiling system, and two options for overall data acquisition and transmission. Option 1 utilizes a measuring, analysis, and transmission system completely separate and disassociated from the on-site meteorological facilities, whereas Option 2 is linked directly to the on-site meteorological system. The main advantage of Option 1 is that it is a separate system, independent of site operations, and guarantees atmospheric measurements whether the on-site meteorological systems are or are not operational. The main advantage of Option 2 is that it utilizes a system already in operation and eliminates securing all of the components associated with Option 1.

All the block components are available as off-the-shelf items and systems like that shown are routinely designed, constructed, and made operational by a number of reputable manufacturers.

2. Data Interfacing

This section describes the interfacing routes of information from the sensing components to the recording mechanism and output for external use.

Each remote station requires information on identification, time, data, location, wind direction, wind speed, and turbulence (σ_θ). The vertical profiler requires identification, time, date, location, wind speed, wind direction, temperature, and pressure information. The telemetry receivers and processors for each system (as shown in Figure 1) are available to provide all necessary information as listed. Most processors have built-in

BLOCK DIAGRAM OF A SMS

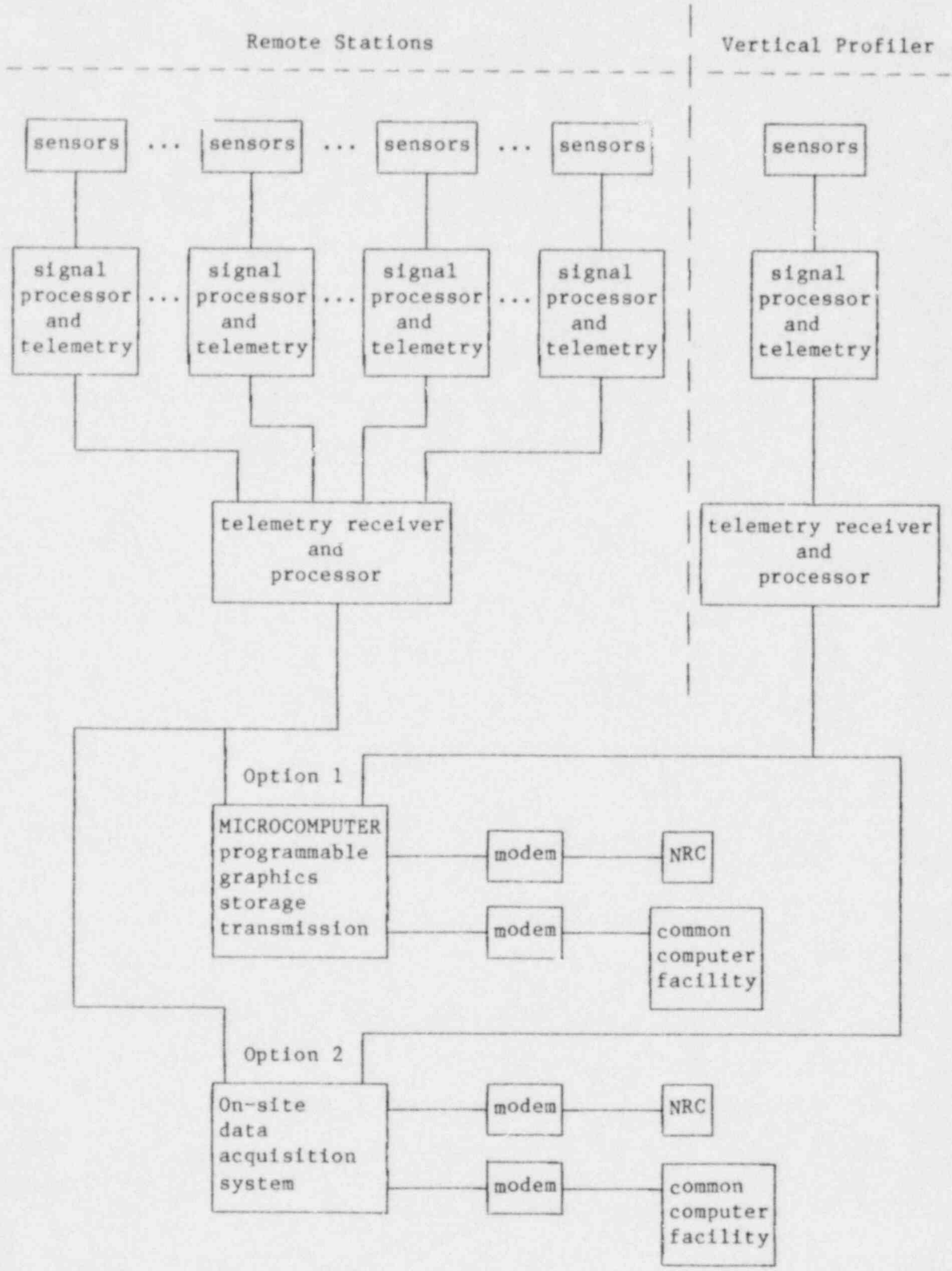

Figure 1

capacities to satisfy the required number of channels needed and are normally expandable. They have RS232C interfacing, and options are available for various output displays and recording. Because of the requirements for storage and transmission, a component system to program, store, and transmit information is recommended. Rapid and recent development of microcomputers has provided the user with small, compact, programmable devices with memories large enough for data processing in a SMS. They can be used to make transport and diffusion estimates, if needed, prior to transmission. Modems, as described in the section on data dissemination, are readily available to interface and control the communications links for external use.

A survey made to determine the availability of off-the-shelf system components, the state-of-the-art interfacing, current analytical procedures and output communications link for a SMS showed that a SMS could be established with available equipment to fulfill the supplemental needs of the NRC.

3. Calibration

A routine schedule to calibrate each individual component separately and collectively to assure system reliability must be maintained. Calibration equipment, traceable to NBS standards and recommended by specific manufacturer of components, should be used in calibration checks. Most remote station systems have built-in calibration checks to monitor performance levels while in operational status. Recording processors can be programmed to tag impossible results to alert users of possible errors somewhere in the overall system. It is recommended that equipment for supplemental use be set up in an operational mode and calibrated every three months when in standby condition. When in actual use, the minimum calibration period should be determined from manufacturer's specifications. It is recommended that an independent calibration audit be made by a reputable organization every six months and that the results be reported to the NRC to assure calibration quality.

4. Maintenance

The components comprising a SMS can normally be maintained by most technical personnel in the field. However, because of rapid development in electronic technology, it is recommended that maintenance contracts be arranged with individual manufacturers or equivalent representatives to assure fast repair to any system component in order to maintain operational status. The manufacturer should establish a list of essential spare parts to be stored with the SMS to expedite repairs. Contracts for preventive maintenance are available and should be considered.

5. Storage

One of the advantages of utilizing a van in a SMS is that it can provide storage for the components when they are not in use. Although meteorological sensing equipment has become less fragile over the years, it still requires special handling and storage facilities. It is recommended that a specific location be designated to store, maintain, and protect this equipment from damage.

Microcomputers, tape drives, and most electronic devices can withstand only a limited range of environmental conditions while in storage as well as when in operation, and those limits should be taken into consideration.

6. Personnel Requirements for Operations

The degree of expertise and time required to set up and operate a SMS must be determined in advance. Although individual components are self-entities and readily put together as building blocks to form a system, technical and professional knowledge is required to determine system operational status and to assure that the requisite data are being obtained.

It is estimated that two people would be required to transport, set up, and reach initial operation condition. After the remote station and/or stations become operational, little further attention is needed. However, the vertical sounding system requires much more time and effort while profiles are being taken.

There is no way to determine how long an incident might last. It could be a few hours to many days. The experience at TMI revealed the importance of proper work scheduling over a period of many days; therefore, it is recommended that a realistic work schedule be established for SMS operation. For 24-hour operation, there should be three 8-hour shifts, each having a meteorological technician and a professional meteorologist.

Radiation protection for personnel operating the SMS must be considered. Acceptable radiation detection badges, clothing, and breathing apparatus should be available when required. Operating personnel should contact on-site radiation officials to assure proper use of radiation protection devices and clothing.

F. Recommendation Review

A survey and an evaluation of off-the-shelf meteorological equipment to assist the NRC in developing criteria for supplemental meteorological instruments for emergency use during incidents at nuclear power plants resulted in the following conclusions and recommendations:

1. Needs

a. A SMS should be designed and implemented with supplemental equipment for use in incident response. It should consist of individual components, be completely portable, have the capability of reaching operational status in a reasonable time period, and be capable of establishing rapid data links.

b. System components should be required to meet the specifications as given in Table I of the ANS-2.5 Guide.

c. All sensor response of no more than one cycle per second should be required.

2. SMS - Remote Stations, Sounder, Data System

a. Remote stations, using conventional equipment, should be considered for use in obtaining information on wind direction, wind speed, and a turbulence parameter at preselected nearby off-site locations.

b. A vertical profiling system should be included in a SMS to supplement data ordinarily obtained from the primary on-site network. It should provide information on wind direction, wind speed, temperature, and height.

c. No remote sensing is recommended at this time.

d. Radiotelemetry communication links should be utilized from sensor components to recording processors.

e. Two modes of communication output should be available for data transmission--one directly to the NRC and the other to a common computer facility.

f. One of two options should be used in processing and transmitting data. One uses computer components in a self-propelled and -powered van, operated and under direct control of NRC personnel; the other utilizes computer and transmission links available at each nuclear facility.

3. Maintenance and Staffing

a. Modular elements for an SMS, should be obtained from a single source of procurement, preferably a reputable manufacturer who provides guaranteed equipment and, if needed, fast repair service.

b. Calibration of systems components and overall system reliability should be made at three-month intervals, and a complete independent audit every six months. Calibration reports and audits should be submitted to the NRC in writing.

c. A maintenance schedule should be followed to assure system operational readiness.

d. Systems component storage should be made available for environmental and damage protection.

e. Consideration should be given to establishing a realistic work schedule for technical and professional personnel for SMS operation.

4. Off-the-Shelf Evaluation

a. The survey showed that there are a number of off-the-shelf components available whose specifications meet those established in various NRC criteria.

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*Available free upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

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16. ABSTRACT (200 words or less)

This document is intended to provide the Nuclear Regulatory Commission with specifications for a Supplemental Meteorological System (SMS) to aid in the response to an incident at nuclear power plant sites. At the time of an incident, there is an immediate operational need to define evacuation areas and to evaluate the consequences of radioactive releases to the atmosphere. Releases can be at any elevation, and knowledge of the upper level winds must be obtained to determine correct trajectory patterns. Sites are situated in nonuniform terrain; therefore, trajectory determination requires knowledge of winds at several points. A measure of stability is required to forecast the degree of horizontal and vertical spreading of effluents.

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